Journal of Forensic and Legal Medicine 17 (2010) 412–420

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/jflm

Original Communication

Comparison of gunshot injuries caused from Tokarev, Makarov and Glock 19 pistols at firing distances of 1, 3 and 5 cm

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ARTICLE INFO

Article history:
Received 9 October 2009
Received in revised form
11 May 2010
Accepted 16 August 2010

Keywords:
Gunshot wounds
Firing distance
Cloth and skin injuries

ABSTRACT

Test shots at cloth and at human skin from autopsy material were performed with 7.62 mm Tokarev (TT), 9 mm Makarov (PM) and 9 × 19 mm Glock 19 pistols, using common ammunition.

The largest central material defects, with fibre deformation in cotton, the largest burn holes in polyester, and also many fibre defects caused by the perforation of powder, were produced in shots from the TT at all distances. Tears in the cloth were longest in the case of the TT at 1 cm and were present at 3 cm, whereas the shots from the PM and the Glock 19 did not leave tears. There were small tears of the edges of the skin defect from shots fired from the TT at 1 and 3 cm. On cloth-soot deposits at 3 and 5 cm, the radial structures of soot resembled a cobweb (the TT), and radial branching structures (the PM) of soot were seen. Some shots from the PM left four shafts of rays of soot and formed the bullet wipe with four narrow and four wide sections, indicating the form of rifling. In the soot deposit from the Glock 19 with hexagonal rifling, hexagonal or polygonal or petal-like areas were visible. On skin, the soot zones were less distinct. The Glock 19 (at 3 and 5 cm) left a lot of gunpowder particles densely around the cloth and skin defect. The least powder left on the cloth and skin was by the PM.

On histological tissue sections, in shots from the TT, a lot of soot and gunpowder residue particles in the epidermis and in both layers of the dermis, and intraepithelial tears and recesses containing soot, were seen. The PM left fine soot and only a few gunpowder particles in the epidermis and in the papillary layer of the dermis. The Glock 19 produced the least soot and a lot of gunpowder particles. The soot and most of the gunpowder particles were present on the tissue sections, which originated from the central area around the skin defect and were detected in the epidermis and in both layers of the dermis. Some tears and recesses in the epidermis were also seen. The further the distance from the centre of skin defect to the periphery, the depth of the penetration of the powder into the skin decreased.

1. Introduction

In close-range shots the presence and extent of tearing and thermal damage of the skin and clothing depend on a number of factors beside muzzle-to-target distance, i.e. the calibre of the weapon, the amount and temperature of gas produced by the combustion of the propellant, the target material and surface condition of the target, and the firmness of the underlying tissues.[1–3] Shots from large- and medium-calibre weapons may cause tears in cloth, not only at contact range but also at near-contact range[1] or more distant (from handguns up to 10–15 cm).[4] Tears of skin can occur from contact range up to 1 cm of distance.[4] The scorching of synthetic and mixed fibre textiles can be detected up to a distance of a few centimetres. In woolen or cotton textiles, the fibres are more resistant to heat.[5] Shots through synthetic clothing may produce large defects of textile with fibres melting together. Some other synthetic textiles and textile from natural fibres may show only superficial scorching.[6] On skin the scorching effect, even when it is present, is often difficult to see beneath the soot layer.[3]

Several other factors, such as the physical form, the charge weight and burning rate of propellant, the muzzle-target angle, and the target material, determine the size, intensity and appearance of the gunpowder residue pattern.[1–3,7–9]

At distances from loose contact up to 1–2 cm, the gunpowder residue may be arranged in two different zones. Around the bullet entrance hole there is usually a dense black powder soot zone, surrounded by a grey, barely visible soot zone.[1,8] At firing distances of 5–10 cm, between them (a central and peripheral zone), on the background of less intensive soot deposits, a more dense radial ray-like pattern (an intermediate zone) may be distinguished.[4] When shots are performed perpendicular to the target surface, the soot pattern will be circular in shape and concentric around the bullet entrance hole.[1]

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doi:10.1016/j.jflm.2010.08.005

For handguns, powder tattooing begins at a muzzle-to-target distance of approximately 1 cm. In near-contact shots a few gunpowder particles may be deposited in the seared blackened area and individual tattoo marks not seen.[1] Depending on the target material and its surface conditions, powder particles are either not found or there are few among the shots at distances of 3–5 cm.[4] The ball powder and, less commonly, flake powder, may penetrate into the upper layer of dermis[1,7] or the powder particles may be found deeper in the reticular layer of dermis.[4]

The aim of the our study was: (1) to investigate the morphologic characteristics of the bullet entrance injuries caused by shots from the Tokarev and Makarov (four lands and grooves), and the Glock 19 (hexagonal rifling) pistols, at firing distances of 1, 3 and 5 cm; (2) to show the influence of rifling of the barrel (the Tokarev and Makarov difference from the Glock 19) to the gunshot residue pattern. This article is a continuation to our previous studies of the same subject.[10,11]

2. Materials and methods

The pistols were selected on the basis of the weapons most commonly encountered in shooting incidents (the TT and the PM) investigated by the Forensic Service Centre of the Estonian Police (since 2008, the Estonian Forensic Science Institute), or with which the Estonian Defence Forces, Estonian Police and Estonian National Defence League are armed (the TT, the PM and the Glock). For test shots we used the most common makes of ammunition available in Estonia. All bullets were full metal-jacketed. Throughout the test with the same pistol we used the same make and lot of ammunition (Table 1). In Fig. 1 are shown the examples of gunpowder grains from the cartridges on 5 mm grids. The TT: grains length 0.8–2.0 mm, diameter 0.7–0.8 mm; the PM: grains length 0.7–1.6 mm, diameter 0.8–0.9 mm; and the Glock 19: grains length 0.4–1.0 mm, diameter 0.5–0.6 mm.

The shots were performed at white, plain woven textiles: 100% cotton ($\sim$142 g/m^2, bleached, 26 $\times$ 24 yarns per 10 mm $\times$ 10 mm, thickness 0.2–0.3 mm, spun threads) and 100% polyester ($\sim$179 g/m^2, 20 $\times$ 20 yarns per 10 mm $\times$ 10 mm, thickness 0.4 mm) cloths. Common finishing techniques were used and no special-purpose finishes affecting the superficial conditions of the textile were applied. For simulation of biological tissues the pieces of cloth with a size of $\sim$20 cm $\times$ 30 cm were fixed to a two-layer rest (foam 0.5–0.6 cm and cardboard 0.2 cm thick). Pieces of skin (autopsy material) from the thigh region *(Regio femoralis)* were obtained from young and middle-aged human cadavers. The pieces of skin were cut by stencil and then were fixed to the cardboard rest. The sizes of skin were 6 cm $\times$ 10 cm, 5 cm $\times$ 15 cm and 6 cm $\times$ 15 cm. The interval between death and shooting was not more than 48 h.

At all distances, 5 shots at cotton and polyester cloth and 2–4 shots at skin, in the horizontal direction at a right angle to the target surface, were performed. During the firing the pistols were fixed between a special bench for firing experiments and the targets were fixed to a thick wooden backstop. After the firings the cloths were photographed by an Olympus C-2000 digital camera. On the photographs, the area of central material defect (absence of a warp and weft yarn) with deformation (unravel and displacement) of fibres, the length of tears in the cloth and the area of soot pattern were measured (by the computer program Soft Imaging System Cell B), and the average numbers of findings were calculated. To

Table 1
Pistols and ammunition used in firings.

Pistols	Ammunition			
	Calibre	Bullet mass	Average muzzle velocity	Manufacturer
Tokarev (TT)	7.62 $\times$ 25 mm	5.5 g	430 m/s	21 RPR 63, Romania
Makarov (PM)	9 $\times$ 18 mm	6.1 g	301 m/s	TPZ, Russia
Glock 19	9 $\times$ 19 mm (9 mm Luger)	7.45 g (115 gr.)	328 m/s	GFL, Italy

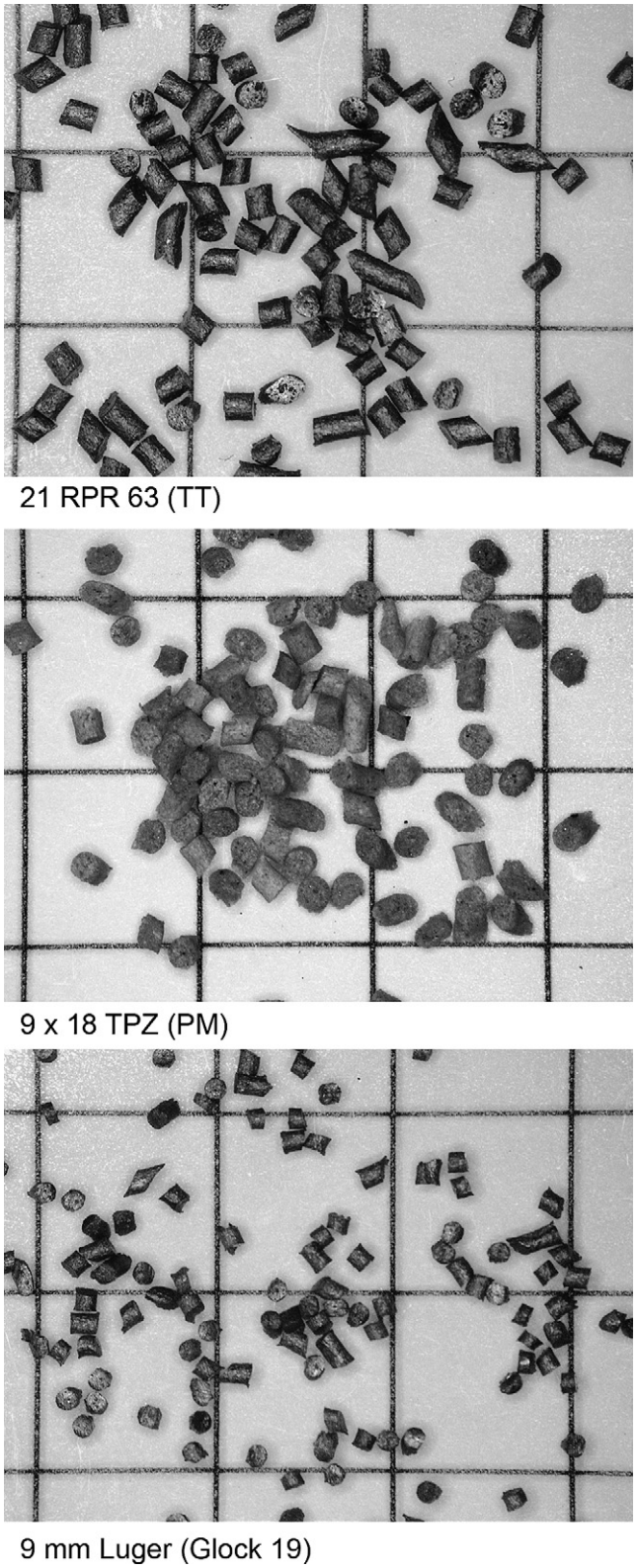

Fig. 1. Examples of gunpowder grains taken from the cartridges used for test shots on 5 mm grids.

determine the distribution and density of the gunpowder residue particles, the particles of the size of at least half of the cotton fibre width and at least one-third of the polyester fibre width were counted under a Nikon SMZ800 stereomicroscope. The marks left by these particles after the impact or penetration through the fibres, and fibre defects (the absence of some part of the fibre) caused by the particles, were also counted. The skin with gunshot wounds was photographed between 1 and 2 h after shooting and fixed in a buffered 4% formaldehyde solution. The specimens were embedded in paraffin and 3–4 μm thick sections were cut. Haematoxylin and eosin stained slides were examined under an Olympus BX60 microscope and photographed with an Olympus Camedia C-3030 Zoom digital camera. The thickness of the epidermis was between 70 and 160 μm and the stratum corneum from 30 to 60 μm. The bullet entrance injuries were examined in 1 cm × 1 cm areas bilaterally starting 1 cm from the centre of the cloth or skin defect.

3. Results

3.1. Central material defect and cloth tears

In cotton cloth, the defect of the bullet entrance injury itself was relatively small, and deformation of the fibres around the defect and tears in cloth were more commonly seen. In polyester cloth, a large defect was formed with hard, partly upturned fibres melted together on the edges of the defect.

The TT: the defect was seen in all cotton cloths when fired at 1 cm and in two out of five cotton cloths when fired at 3 cm and 5 cm. In polyester cloths, large burn holes were left. The PM: with the increase of distance, the defect decreased and the deformation of fibres predominated. The Glock 19 caused the defect in cotton at a firing distance of 1 cm, in polyester at the distances of 1 cm and 3 cm, whereas at 5 cm only melting of the ends of individual synthetic fibres were produced.

Longer tears in cloth were mainly parallel to the warp yarn (according to numbers 3 and 9 by the face of a clock). Shots from the TT produced in addition to cruciform tears, many shorter tears in different directions (especially in cotton at 3 cm). Linear tears in two cotton cloths and in four polyester cloths, and one tearing in three parts of polyester were formed from shots fired from the PM at 1 cm. No tears in the cloth occurred when fired at 5 cm (Table 2).

Table 2
Average area of central material defect with fibre deformations and average length of tears by the face of a clock in cotton (c) and polyester (p) cloths.

Pistols	Firing distance, cloth material	Material defect with fibre deformations (mm^2)		Length of tears by the face of a clock (mm)			
		Defect	Deformation	12	3	6	9
Tokarev	1 cm, c	79.3	271.2	45.4	76.7	55.8	71.5
	1 cm, p	588.3	0	63.1	61.8	61.8	58.6
	3 cm, c	4.1	225.5	9.9	15.3	10.0	16.7
	3 cm, p	133.9	0	21.0	22.3	28.2	33.2
	5 cm, c	1.4	79.4	0	0	0	0
	5 cm, p	17.6	0	0	0	0	0
Makarov	1 cm, c	40.1	35.6	0	8.0	0	8.0
	1 cm, p	55.2	48.0	2.0	19.2	0	19.7
	3 cm, c	1.7	46.9	0	0	0	0
	3 cm, p	3.5	28.6	0	0	0	0
	5 cm, c	1.0	54.3	0	0	0	0
	5 cm, p	0.7	45.3	0	0	0	0
Glock 19	1 cm, c	33.7	91.2	37.2	51.2	40.1	48.9
	1 cm, p	222.5	0	42.2	46.4	44.6	39.7
	3 cm, c	0	82.6	0	0	0	0
	3 cm, p	8.5	20.5	0	0	0	0
	5 cm, c	0	58.1	0	0	0	0
	5 cm, p	0	33.7	0	0	0	0

3.2. Soot pattern on cloth

By the intensity and structure of soot deposits, different zones were distinguished – concentrically arranged around the material defect, named as: a central, an intermediate and a peripheral soot deposit zone.

The TT: at a distance of 1 cm in general, a greyish-black elliptical (on cotton) and rhomboid (on polyester) soot area was surrounded by grey cloud-like peripheral soot zone. The central and the intermediate zone were run together or were fragmentary distinguishable on cotton. At 3 cm, a greyish-black central zone with a diameter 31.0 mm on cotton and 34.0 mm on polyester cloth was left. In the intermediate zone, a lighter area (with a sharp circular outer contour) followed by a ray-like area was seen. At 5 cm, a star-like central zone with a diameter of 24.0 mm on cotton and 31.0 mm on polyester was left. In the intermediate zone, radial structures of soot resembled a cobweb. When fired at 3 cm and 5 cm, the peripheral zones were light grey and blossom-like. The diameter of the soot pattern produced increased from 123.5 mm and 113.0 mm (fired at 1 cm) to 163.0 mm and 146.0 mm (fired at 3 cm), and then up to 189.0 mm and 200.0 mm (fired at 5 cm) accordingly on cotton and polyester cloth.

The PM: at a distance of 1 cm, in general, a black round-shaped soot deposit was surrounded by a frizzy peripheral zone. On cotton in most shots, inside that soot area, a central zone (26.1 mm in diameter) with a hardened cloth surface was distinguishable. At 3 cm and 5 cm, a bullet wipe (ring of dirt) was detected, and on some cloths it formed four narrow and four wide sections. A more or less circular central zone was 26.0 mm and 19 mm (fired at 3 cm) and 27.0 mm and 21.0 mm (fired at 5 cm) in diameter respectively on cotton and polyester cloth. In the intermediate zone, radially branching structures similar to four shafts of rays branching outward and forming triangular areas could occur. The peripheral zones were lighter and blossom-like. The diameter of the soot pattern on cotton and polyester cloth was 118.5 mm and 121.5 mm (at 1 cm), 131.0 mm and 137.0 mm (at 3 cm) and 142.0 mm and 186.0 mm (at 5 cm).

The Glock 19 produced the least soot. At a distance of 1 cm, around the defect, a light area (31.9 mm in diameter on cotton, fragmentary on polyester) followed by a dark area was formed. In general, an elliptical (on cotton) and rhomboid (on polyester) soot deposit was left. The peripheral zone was light brown and cloud-like. When fired at 3 cm and 5 cm, a black petal-like central zone was formed. The diameter of the central zone was 29.6 mm and 29.7 mm (at 3 cm) and 32.9 mm and 31.6 mm (at 5 cm) accordingly on the cotton and polyester cloth. In the intermediate zone, on cotton a hexagonal (at 3 cm) or a less contoured polygonal (at 5 cm) area, and on polyester cloth a petal-like (at 3 and 5 cm) light area surrounded by soot rays, was visible. The peripheral zones were cloudy, barely visible soot halos. The diameter of the soot pattern increased from 80.0 mm and 75.0 mm (at 1 cm) and 135.0 mm and 111.5 mm (at 3 cm) to 144.5 mm and 120.5 mm (at 5 cm) accordingly on cotton and polyester cloth (Figs. 2 and 3).

3.3. Deposition of gunpowder residue particles on cloth

The TT caused many fibre defects at all distances, especially into the cotton cloth. The gunpowder residue particles were dispersed on the cloths with a decreasing number towards the peripheral area of the target.

The shots from the PM caused only one mark due to the impact with powder particles (at 3 cm) with fewer powder particles left on the cloths (at 5 cm), but not defects.

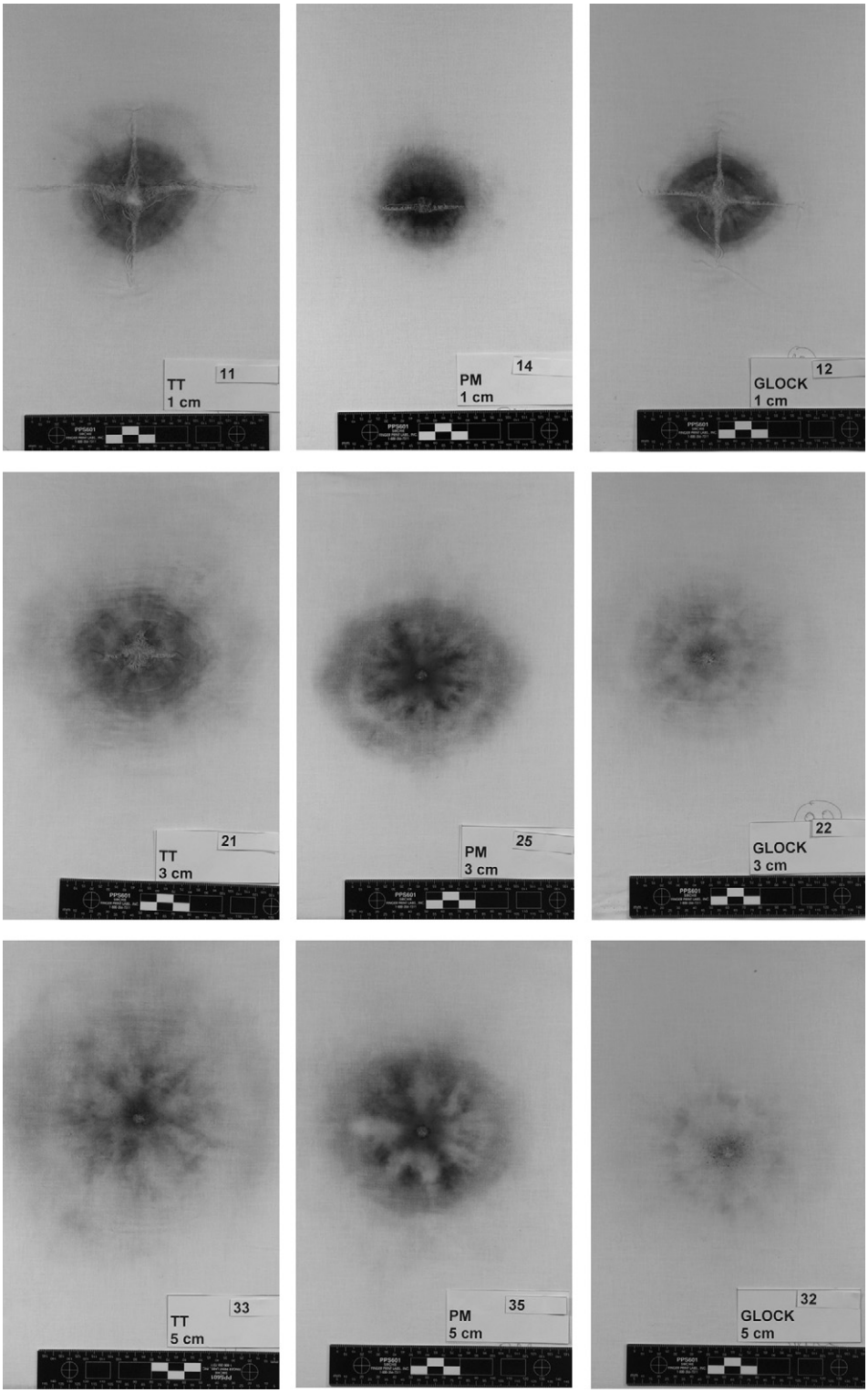

Fig. 2. Macroscopic pattern of soot and gunpowder residue particle distribution on cotton cloths.

The shots from the Glock 19 at the distances of 3 cm and 5 cm left the greatest number of greenish-yellow gunpowder particles and they were located mostly around the central material defect. On polyester, the area at the central zone of the soot deposit was hard and rough to the touch due to the strong adherence of particles to the material. Figs. 4–6 present the results found on 5 cloths bilaterally from the central material defect.

3.4. Macroscopic findings of skin

The TT: a large amount of soot at all distances. At a distance of 1 cm the dense central zone was surrounded by a cloud-like peripheral zone, and a few powder particles were noticeable on the background of the soot. At 3 cm and 5 cm, around the star-like central zone, the radial intermediate zone and cloudy, barely visible

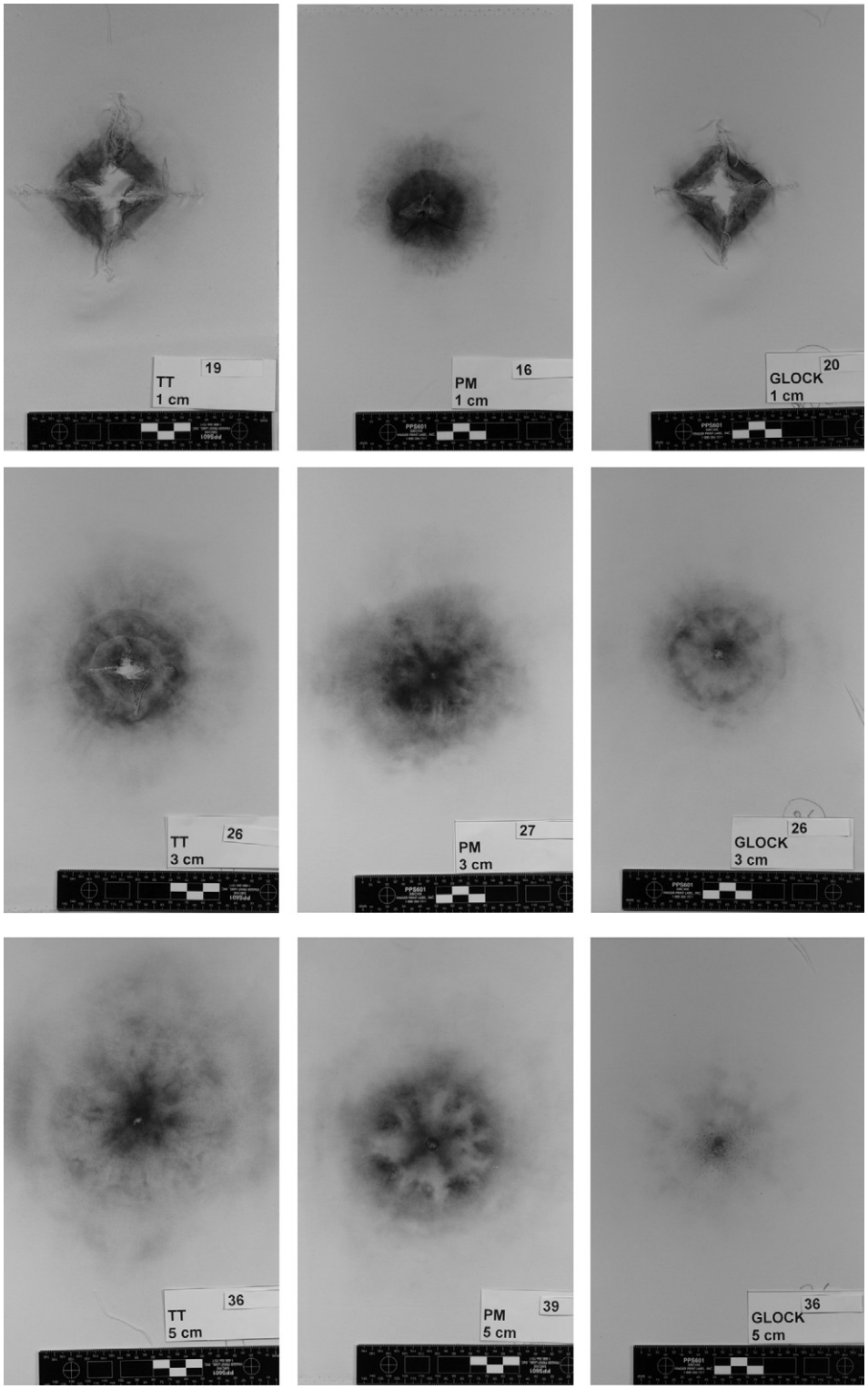

Fig. 3. Macroscopic pattern of soot and gunpowder residue particle distribution on polyester cloths.

peripheral zone of soot were distinguishable. A lot of black gunpowder residue particles (especially at 5 cm) were seen. There were small tears of the edges of the skin defect, no longer than 1–1.5 mm, when fired at 1 cm and 3 cm.

The PM: a lot of soot (especially at 1 cm) arranged in the central and peripheral zones, and when fired at 3 cm and 5 cm, the intermediate zone resembled rays or four fans (at 5 cm) were also left. Only a few gunpowder grains on the skin surface were seen when the firing distance was 5 cm.

The Glock 19: little soot and a lot of greenish-yellow gunpowder grains at all distances. The soot with powder grains was located densely around the skin defect and faintly on the peripheral area, where the soot was beginning to fade at a distance of 5 cm. The soot pattern was circular or a bit petal-like in shape.

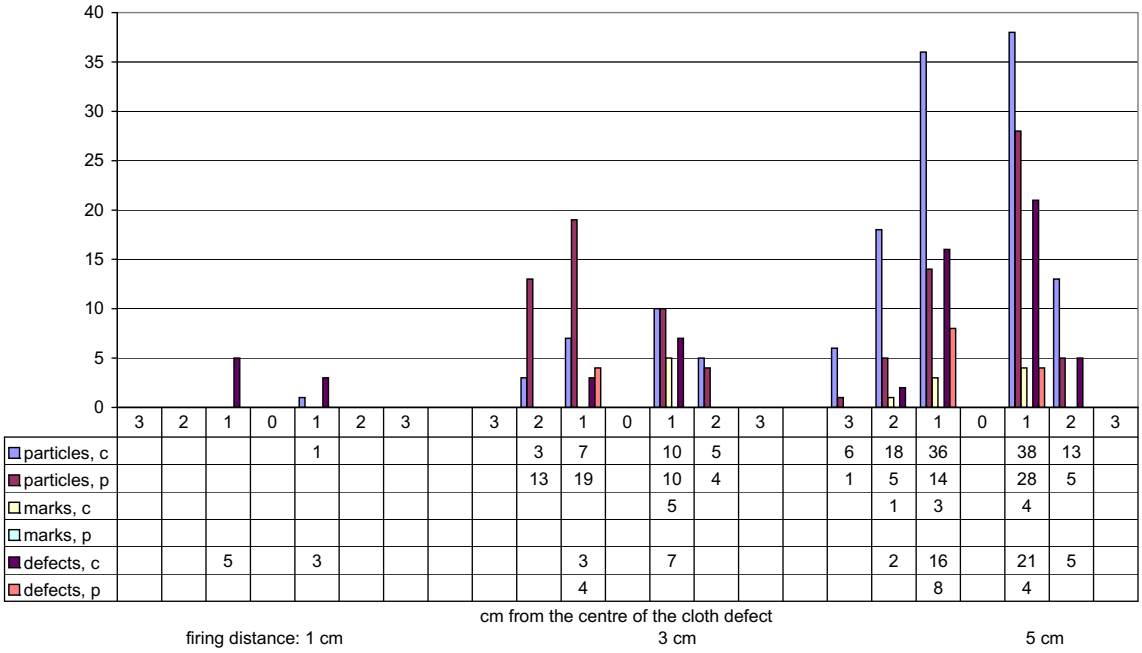

Fig. 4. Number of gunpowder particles, impact or penetration marks and fibre defects on cotton (c) and polyester (p) cloths in shots from the 7.62 mm Tokarev.

3.5. Microscopic findings of skin

The TT: on the histological preparations, the soot was seen on the tissue sections from 1 to 4 cm from the centre of the skin defect. The gunpowder residue particles were seen up to 3 cm (fired at 1 cm) and up to 4 cm (fired at 3 and 5 cm) from the centre of skin defect. In the central areas around the defect, they had penetrated into the epidermis and deeper down to both layers of the dermis, corresponding to the depths of 400 μm (at 1 and 3 cm) and 580 μm (at 5 cm). Also several intraepithelial tears and recesses containing soot were seen in central areas. In the skin areas 2–4 cm from the centre of the defect, the location of powder was uneven: they could be found on the skin surface and down to the depths of 170–180 μm.

The PM: on the histological tissue sections, the fine soot was found up to 3 cm (fired at 1 cm) and up to 4 cm (fired at 3 and 5 cm) from the centre of the defect, and it was on and in the epidermis. The number of gunpowder residue particles was smallest and they were present in central areas down to the papillary layer of the dermis, down to the depth of 100 μm (at 3 cm) and 170 μm (at 5 cm). When the firing distance was 1 cm, one or two partially burnt powder particles on the skin surface were seen.

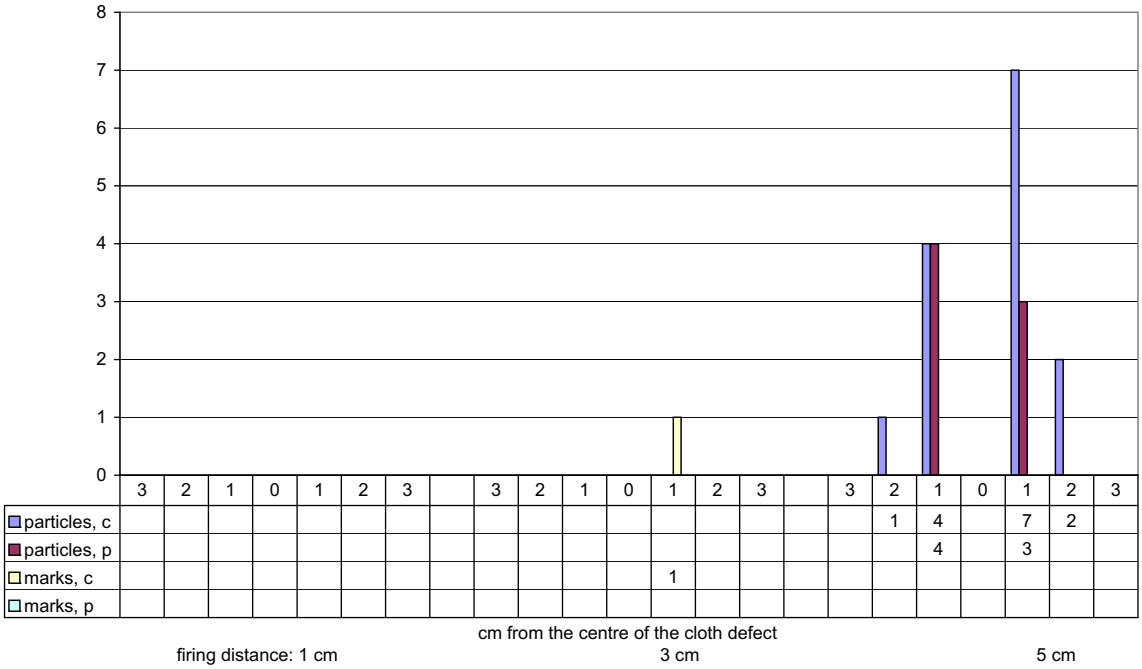

Fig. 5. Number of gunpowder particles and impact or penetration marks on cotton (c) and polyester (p) cloths in shots from the 9 mm Makarov.

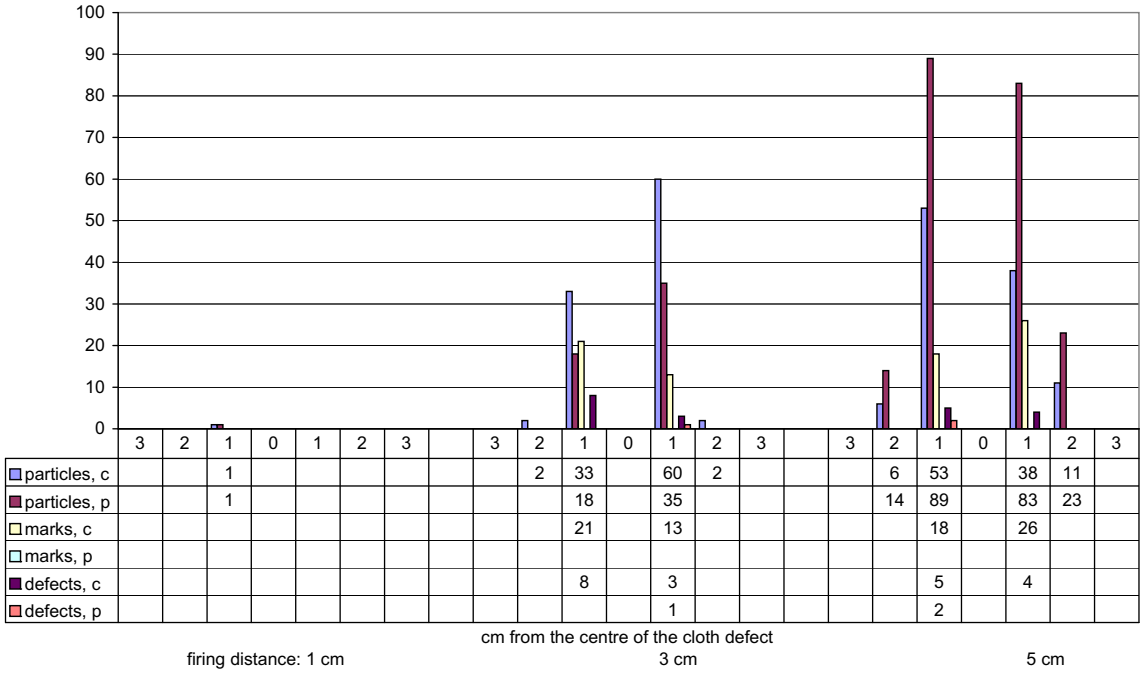

Fig. 6. Number of gunpowder particles, impact or penetration marks and fibre defects on cotton (c) and polyester (p) cloths in shots from the 9 × 19 mm Glock 19.

The Glock 19: the soot and most of the gunpowder particles were present on the tissue sections, which originated from 1 to 2 cm from the centre of the defect. A few powder particles were found also in the tissue slides, which were taken from the areas of 2 to 4 cm from the centre of the defect (fired at 3 and 5 cm). In the central areas the powder particles were detected in the epidermis and in both layers of the dermis down to the depths of 350 μm (at 1 cm), 320 μm (at 3 cm) and 400 μm (at 5 cm). Also some tears and recesses in the epidermis were seen. In the areas of 2–3 cm in shots at 3 cm, the depth of penetration of the powder particles was down to 50 μm into the epidermis, and when fired at 5 cm, down to 160 μm into the papillary layer of dermis. In the areas of 3–4 cm, the powder was more superficially down to the depth of 20 μm (at 3 cm) and 50 μm (at 5 cm) (Fig. 7).

4. Discussion

The appearance of the signs of close-range shots is related to a number of factors in addition to the muzzle-to-target distance.[1–3] In our test shots we investigated the influence of the type of pistol (in connection with different forms of rifling) and target material, performing shots with the same make and lot of ammunition throughout the present and previous studies.[10,11]

According to Popov et al.[4] tears in cotton cloth may occur up to a distance of 5 cm (fired from the TT) and up to 3 cm (from the PM); in different synthetic cloths up to 5–15 cm (from the TT) and at contact up to 5 cm (from the PM); in skin up to 1 cm of distance. Signs of heat damage due to incandescent gases or impact with hard particles on cotton cloth can be found up to 3–5 cm (the TT and the PM), and the melting of the ends of synthetic fibres up to 15–80 cm (the TT) and up to 30–50 cm (the PM). Contact shots from the PM[12] produced large defects in synthetic materials with melting and the turning up of edges. In shots at 5 cm, the melted tips of individual fibres of entrance injury and hollows with melted bottoms by the impact of gunpowder grains were seen.

In our study, the largest material defects with deformation of fibres were caused by shots from the TT at all distances. Concerning the tears, they were the longest in shots from the TT at 1 cm and were present at 3 cm in cloth, and were seen at 1 cm and 3 cm of distances in skin.

According to Zakaras and Marchenko,[13] in shots from the TT and the PM, at the firing distances of 2–5 cm, three zones appeared in the soot deposit and powder was present on textiles. When fired from the PM, the intermediate zone had patterns of radial structures. More exactly, in the soot deposit left by the PM at 5 cm on cotton cloth, four zones were found by Gliko.[14] As described by the author, between the central and peripheral zone was a less intense light grey soot zone, which was surrounded by radial soot deposits triangular in shape, where the base of the triangle was pointed at the periphery and the tip to the centre. These triangular areas may be up to 12 in number, but sometimes they are not distinct and not all of them can be distinguished.

In the shot from the PM at cotton, a steady increase of the area of the central soot zone from contact to 5 cm incl. was found. Beyond a distance of 5 cm, the outer border of the central zone was not distinctly visible and therefore the size of the zone was not measurable.[15] In another context, the relationship between the size of the zones and firing distance which allows the determining of the firing distance was not found.[13,14]

We described the soot deposit left at 3 cm and 5 cm by three zones, as these zones were the most clearly distinguishable by their intensity. In our test the average diameter of the whole soot pattern increased by increasing the firing distance. But as the central zone formed on all cloths starting at a distance of 3 cm and individual differences between shots exist, we drew no conclusions about the probable relationship between the size of the central zone and firing distance. At a distance of 1 cm on cloth, the TT and the PM formed black soot deposits on the edges of the defect, but the Glock 19 left a light area. At 3 cm and 5 cm, radial structures resembled a cobweb (the TT) and radially branching structures (the PM) in soot deposit were seen. On some cloths, the PM left four shafts of rays and the bullet wipe had four narrow and four wide sections indicating to the form of rifling. In shots from the Glock 19 with hexagonal rifling, the findings were different: hexagonal or polygonal or petal-like

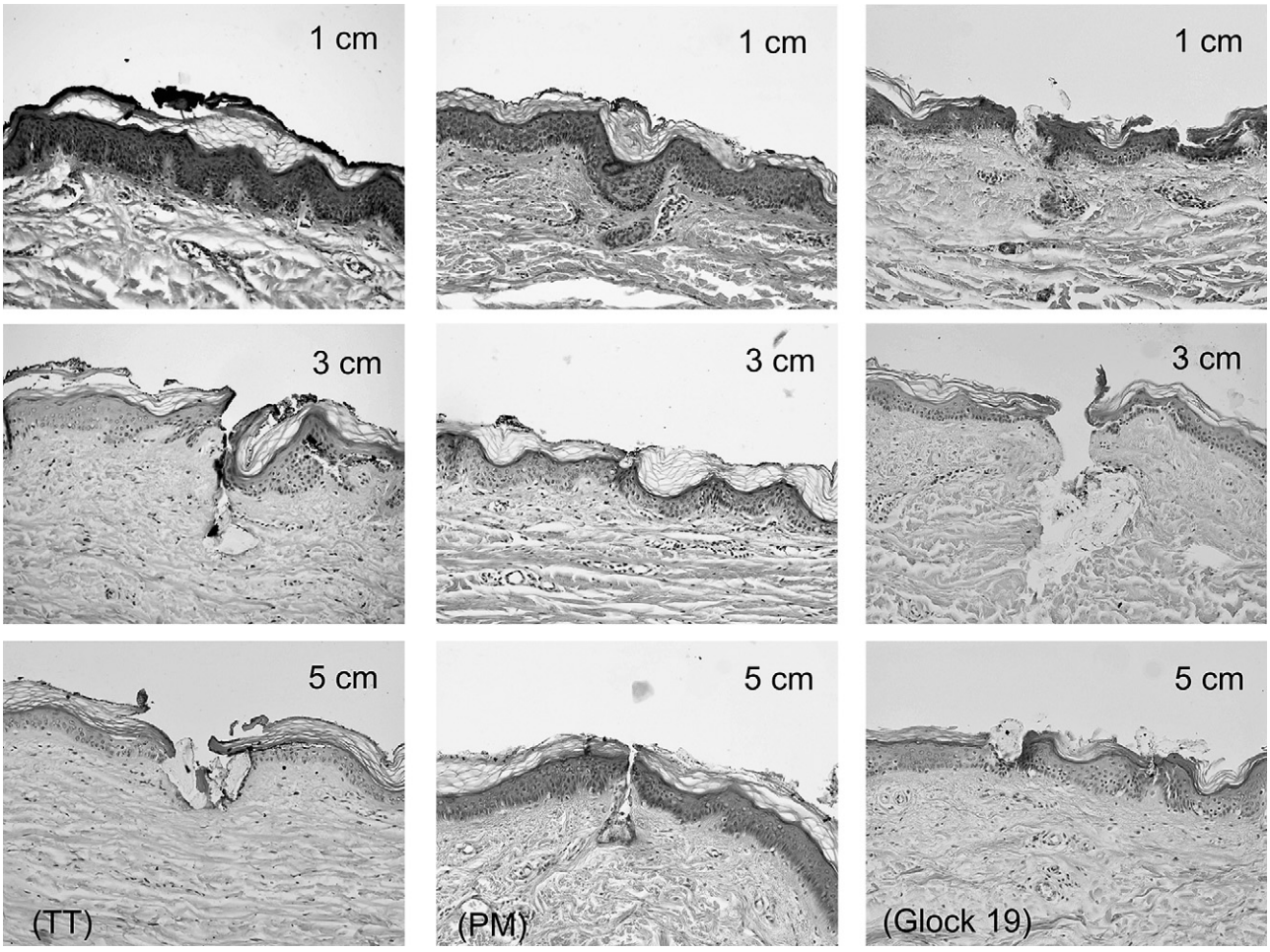

Fig. 7. Soot and gunpowder residue particles in shots from the 7.62 mm Tokarev (TT), 9 mm Makarov (PM) and 9 × 19 mm Glock 19 pistols at the distances of 1, 3 and 5 cm.

areas in soot deposit were visible. On the skin, in shots from the TT and the PM, all three soot zones were recognisable, but the borders and shape of zones were less distinct. The Glock 19 left the least soot and the borders of zones were diffuse, the shape of soot deposit was circular or a bit petal-like and no radial structures were formed.

The tests shots performed by Janssen showed that when the thickness of the target material and smoothness of the surface increased, the intensity and the diameter of the smoke-stained area started to decrease when compared to less dense material at the same distance. At first the outer zone of soot started to decrease and then the soot in the centre.[16]

In our test, the diameter of the soot pattern was bigger on cotton than on polyester in shots from the TT (at 1 and 3 cm) and the Glock 19 (at all distances). Shots from the PM gave the opposite result, similarly to the data given by Popov et al.,[4] where the finding is explained as follows: cotton has better soot and powder absorbing properties than synthetic material, whereas the soot seems to flow over a smooth surface of textile, forming bigger soot zones on synthetic cloth.[4] For drawing conclusions about the influence of the surface properties of the target material is necessary to consider the results obtained at more distant firing ranges too.

One or two gunpowder particles, resulting from 10 cloths, were seen when fired at 1 cm from the TT and the Glock 19 and not found in the case of the PM, which left the least gunpowder at following distances. The greatest number of gunpowder particles at the distances of 3 cm and 5 cm were in shots from the Glock 19, and they were located mostly around the central material defect. The greatest number of fibre defects produced by perforation by powder was in shots from the TT at all distances (especially many in cotton). On polyester, the powder perforated the material less and remained at the place of impact more frequently. The least soot was left in shots from the Glock 19 on the cloth and skin. On the histological tissue sections, in shots from the TT, a lot of soot and gunpowder residue particles and intraepithelial tears were seen, whereas in shots from the PM only a few gunpowder residues, superficially with fine soot, were left. In the case of the Glock 19, we noticed that the gunpowder particles located in the skin deeper in central area of the target, and were superficially in the peripheral areas of the target.

5. Conclusion

Comparing the bullet entrance injuries produced in shots from the Tokarev, Makarov and Glock 19 pistols at distances of 1, 3 and 5 cm, we observed differences in the following:

(1) The size of the defect with deformation of fibres and length of tears in cloth
(2) The density and structure of soot deposit on the cloth and skin influenced by rifling of the weapons barrel
(3) The distribution and the density of the gunpowder particles on the cloths
(4) The distribution and the depth of penetration of the gunpowder particles on the skin

The results were similar on the cloth and on the skin and were in correlation of the firing distance.

Conflict of interest

None.

Funding

No funding.

Ethical approval

For using pieces of human skin, approval from the Ethics Review Committee of Human Research of the University of Tartu (no. 91/2, 26.02.2001) has been obtained.

Acknowledgements

The authors are grateful to firearm experts from the Estonian Forensic Science Institute for their help in conducting test firing sessions.

References

1. Di Maio VJM. *Gunshot wounds. Practical aspects of firearms, ballistics, and forensic techniques*. 2nd ed. Boca Raton London New York Washington, DC: CRC Press; 1999. p. 71–75, 141–144, 336–340.
2. Barnes FC, Helson RA. An empirical study of gunpowder residue patterns. *J Forensic Sci* 1974;**19**(3):448–62.
3. Heard BJ. *Handbook of firearms and ballistics. Examining and interpreting forensic evidence*. Chichester New York Brisbane Singapore Toronto: John Wiley and Sons Ltd; 1997. p. 161–177.
4. Popov VL, Shigeev VB, Kuznetsov LE. *Sudebno-meditsinskaia ballistika*. Sankt-Peterburg: Gippokrat; 2002. p. 194–200, 412–425.
5. Berg S. Veränderungen der Textiloberfläche bei Nahschüssen. *Arch Kriminol* 1959;**124**:5–8.
6. Pollak S. Zur Makro- und Mikromorphologie der durch Faustfeuerwaffen erzeugten Einschußwunden. *Beitr gerichtl Med* 1982;**40**:493–520.
7. Di Maio VJM, Petty CS, Stone IC. An experimental study of powder tattooing of the skin. *J Forensic Sci* 1976;**21**(2):367–72.
8. Plattner T, Kneubuehl B, Thali M, Zollinger U. Gunshot residue pattern on skin in angled contact and near contact gunshot wounds. *Forensic Sci Int* 2003; **138**:68–74.
9. Haag LC. Physical forms of contemporary small-arms propellants and their forensic value. *Am J Forensic Med Pathol* 2005;**26**(1):5–10.
10. Lepik D, Vasiliev V. Comparison of injuries caused by the pistols Tokarev, Makarov and Glock 19 at firing distances of 10, 15 and 25 cm. *Forensic Sci Int* 2005;**151**:1–10.
11. Lepik D, Vasiliev V, Reisenbuk H, Põldsam Ü. Comparison of injuries caused by the pistols Tokarev, Makarov and Glock 19 at firing distances of 25, 50, 75 and 100 cm. *Forensic Sci Int* 2008;**177**:1–10.
12. 17. Deriĭ SV. Izmeneniia sinteticheskikh volokon v oblasti vkhodnykh ognestrel'nykh otverstiĭ. [[Changes in synthetic fibres in the region of gunshot entry holes]]. *Sud Med Ekspert* 1970;**13**(4):20–2.
13. Zakaras AP, Marchenko MI. Kharakteristika povrezhdeniĭ odezhdy, prichinennykh vystrelami iz malogabaritnogo samozariadnogo pistoleta (PSM) kalibra 5,45 mm v sravnenii s pistoletami Tokareva (TT) kalibra 7,62 mm i Makarova (PM) kalibra 9,0 mm. [[Characteristics of clothing damage caused by shots from small-size self-loading 5,45 mm pistol (PSM) as compared with 7,62 mm Tokarev pistol (TT) and 9,0 mm Makarov pistol]]. *Sud Med Ekspert* 1982;**25**(4):34–6.
14. Gliko LI. Ob ustoĭchivosti priznakov blizkogo vystrela iz pistoleta "PM" i avtomata "AK". [[The stability of characteristics of close-range discharge from the "PM" pistol and "AK" machine gun]]. *Sud Med Ekspert* 1968;**11**(3):10–3.
15. Kupov II A, Zharikov PM, Belova IV , Enikeeva AKh. O vozmozhnosti konkretizatsii blizkoĭ distantsii vystrela iz pistoleta Makarova. [[Possibility of specifying the near distance of a shot from a Makarov pistol]]. *Sud Med Ekspert* 1981;**24**(4):19–20.
16. Janssen W. Nahschusszeichen auf Kunstfaserstoffen unter besonderer Berücksichtigung der Oberflächenstruktur. *Dtsch Z ges Gerichtl Med* 1966;**58**: 112–21.